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				5c. PROGRAM ELEMENT NUMBER	
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14. ABSTRACT <p>The objective of this basic research effort is to provide theoretical guidance to enable enhanced radar, imaging, and communication by designing novel emitters based on concepts from EM wavelet theory. The PI will undertake the theoretical and numerical descriptions of EM wavelet emission. This requires the description of realizable currents on various surfaces. These currents are a direct result of earlier work supported by AFOSR wherein the PI examined Maxwell's equations from a perspective of complex space-time and pulsed-beams. Using his extension of Dirac delta functions into this complex environment he was able to predict the creation of very narrow beams and it is these beams whose currents need to be realized. The AF would benefit from the ability to create very narrow MW beams from small sources and this research promises such devices.</p>					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON GERALD KAISER
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER (Include area code) 8042623777

# FINAL REPORT

**AFOSR Grant # FA9550-08-1-0144**

**15 March 2008 - 30 November 2010**

**No-Cost Extension: 1 December 2010 - 31 March 2011**

**Date completed: April 2, 2011**

## GRANT TITLE:

*Pulsed-Beam-Wavelets and Their Sources: Applications to Radar, Imaging and Communications*

PI Name: Gerald Kaiser

PI Address: 3803 Tonkawa Trail #2, Austin, TX 78756

PI Phone: 512-300-8065

PI Fax: 512-300-8065 (Prefer email attachments; please call to notify of fax)

PI email address: [kaiser@wavelets.com](mailto:kaiser@wavelets.com)

## A. ORIGINAL OBJECTIVES:

1. Continue working with Dr. Albanese and his team to build EM wavelet antennas.
2. Finalize the formulation of realizable currents on spheroidal shells for launching electromagnetic wavelets by investigating their material structure (metal, plasma, etc.).
3. Further develop the reciprocal theory of pulsed-beam wavelet emitters and receivers.
4. Give a lecture series on Pulsed-BeamWavelets and Their Sources: Applications to Radar, Imaging and Communications for EE graduate students and faculty at various engineering conferences and academic institutions.
5. Implement wavelet radar as conceived in [K96] using the new EM wavelet antennas.

## B. OBJECTIVES ADDED DURING GRANT PERIOD:

1. Formulate generalized Huygens principles for scalar and electromagnetic pulsed-beam wavelets. This was accomplished in 2009-2010.
2. Construct *coherent* electromagnetic pulsed-beam wavelets, which have *no reactive energy*. This was accomplished in January-March 2011.

## STATUS OF EFFORT

[A brief statement of progress towards achieving the research objectives. Please make this substantive (Limit to 200 words).]

1. With Drs. Devaney, Marengo, Albanese, and Erdmann, we have solved an inverse source problem enabling the construction of electromagnetic wavelets. This covers Objectives 1 and 2 above.
2. With Thorkild Hansen, I have proved generalizations of Huygens principle where the spherical Huygens wavelets are replaced with pulsed-beam wavelets. This can be

applied to reception as well as emission processes, and in particular it covers Objective 3 above.

3. I have developed a formulation of the Stratton-Chu and the Kottler-Franz equations in electrodynamics in terms of *distributions* (generalized functions) supported on a (Huygens) surface surrounding the charge-current density. This facilitates the implementation of the pulsed-beam Huygens principle to electromagnetic fields.
4. In June 2008 and April 2009, I gave one-week short courses on electromagnetic wavelets and their applications to communication at the University of Oviedo Telecommunications School, Gijon, Spain. The audience consisted of faculty and graduate students from various universities. I have also given lectures at UTSA (March 2008 and January 2009), UCLA (April 2010), and Caltech (April 2010). This covers Objective 4 above.

#### ACCOMPLISHMENTS/NEW FINDINGS

[Describe research highlights, their significance to the field, their relationship to the original goals, their relevance to the AF's mission, and their potential applications to AF and civilian technology challenges.]

1. The generalization of Huygens principle to pulsed-beam wavelets was a major discovery since it enables the representation of arbitrary acoustic and electromagnetic fields as a superposition of pulsed-beam wavelets.
2. As an added bonus, the pulsed-beam representation electromagnetic waves gives a natural numerically fast method for computing radiation and scattering fields.
3. I believe the newly discovered *coherent electromagnetic wavelets* could have some very interesting potential applications because they have no reactive energy and should therefore radiate very efficiently.

#### PERSONNEL SUPPORTED

[List professional personnel supported by and/or associated with the research effort.]

David Park

1429 Searchlight Way

Mount Airy, MD 21771-7704

Mathematica programming & graphics consulting

Total of 44 hours at \$40/hour

#### PUBLICATIONS

[List peer-reviewed publications submitted and/or accepted during the 12-month period starting the previous 1 August (or since start for new grants).]

1. The Inverse Source Problem for Wavelet Fields, published in IEEE Transactions on Antennas & Propagation Vol. 56 No. 10, 2008
2. [Generalized Huygens principle with pulsed-beam wavelets](#), published in J. Phys. A: Math. Theor. 42 (2009) 475403

3. [Huygens' principle in classical electrodynamics: a distributional approach](#), submitted for publication in J. Phys. A on March 8, 2011
4. [Coherent electromagnetic wavelets and their twisting null congruences](#), submitted for publication in J. Phys. A on March 6, 2011
5. Huygens' Principle for Complex Spheres, accepted for publication by IEEE Transactions on Antennas & Propagation, April, 2011

BOOK IN PREPARATION (8 of 12 chapters completed):

*Electromagnetic Wavelets and Their Sources*, under contract for *Progress in Mathematical Physics* book series, Birkhauser-Boston.

## INTERACTIONS/TRANSITIONS

Participation/Presentations At Meetings, Conferences, Seminars, Etc.

[Be selective, but be sure to include participations that reflect the quality / impact of the effort]

1. *Making electromagnetic wavelets*. Mathematics Colloquium, University of Texas at San Antonio, March 28, 2008
2. *Generalized Huygens principle using pulsed-beam wavelets*. Mathematics Department Seminar, UT-San Antonio, January 13, 2009
3. *Complex Huygens principles as efficient representations of wave fields*, Caltech, April 19, 2010
4. *Complex Huygens principles as efficient representations of wave fields*, [IPAM \(UCLA\), April 16, 2010](#)
5. 6/23-27/08: Short course (1 week) on *Electromagnetic wavelets and their applications to communication*, University of Oviedo Telecommunications School, Gijon, Spain
6. 4/14-17/09: Short course (1 week) on *Generalized Huygens principle with pulsed-beam wavelets*, University of Oviedo Telecommunications School, Gijon, Spain

## \* Consultative And Advisory Functions To Other Laboratories And Agencies

[Consultative and advisory functions to other laboratories and agencies, especially Air Force and other DoD laboratories. Provide factual information about the subject matter, institutions, locations, dates, and name(s) of principal individuals involved.]

1. I gave lectures at Brooks City Base in San Antonio to Dr. Albanese and his group on the following dates: 3/28/08, 5/12/08, 3/22/09, 3/23/09, 5/6/09, 7/15/09.
2. I gave presentations of my research at the AFOSR Electromagnetic Workshop in San Antonio on 1/6/09, 1/5/10, and 1/5/11.

## NEW DISCOVERIES, INVENTIONS, OR PATENT DISCLOSURES

[If none, report None.]

None.